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Finfish Maturity Sampling and Classification Schemes Used during Northeast Fisheries Center Bottom Trawl Surveys, 1963-89

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ABSTRACT

A variety of maturity stage classification schemes have been employed during the Northeast Fisheries Center (NEFC) bottom trawl survey series. Analyses of resulting maturity data depend, to some extent, upon an understanding of the differences between these schemes. The NEFC Reproductive Biology Working Group has identified the need to document the history of survey maturity sampling and compile this information in a citable report.

This report provides a brief background of events relating to survey maturity sampling and summarizes in tabular form the various classifications used during 1963-89. During this period, maturity sampling was expanded from two species to more than 30 species, and resulted in perhaps the most extensive time series of maturity information in existence. Over this same period, macroscopic maturity staging criteria have evolved from generic literature-based values to detailed, species-specific criteria derived from observations of collected data.

INTRODUCTION

Fisheries scientists have long recognized the need to study reproductive biology in order to depict stock dynamics. One such aspect is the systematic determination of gonadal maturity stages; not only must mature individuals be distinguished from immature ones, but the progression of the various developmental stages must be observed to delineate spawning cycles.

When the Woods Hole Biological Laboratory of the Bureau of Commercial Fisheries (BCF, now the National Marine Fisheries Service) undertook a bottom trawl survey program in 1963, at-sea collection of maturity information was limited to two species. By the early 1980s, maturity sampling had been expanded to include 32 species. Over this period, the macroscopic criteria employed for maturity determinations have undergone substantial evolution and refinement which, for the most part, have not been documented adequately. In this report, we provide the background for the original maturity staging scheme used by the survey program and summarize in tabular form the numerous revisions of these criteria during a 27-year bottom trawl survey time series. All tables are presented virtually in their original form and text; any editorial changes have been enclosed in squared brackets.

BACKGROUND ON ORIGINAL CRITERIA

The earliest maturity classification scheme was devised by Hjort (1910) based upon gross morphological observations of gonads from Atlantic herring (*Clupea harengus*). The seven-stage "Hjort scale" (Table 1) was widely used over the next few decades, and underwent a minor modification in 1929 in the form of an eighth stage ("Resting") proposed by Buckmann (1929). In 1960, the United Nations Food and Agriculture Organization (FAO) adopted Buckmann's eight-stage scheme (Table 2) for inclusion in its series of *Manuals in Fisheries Science* (Kesteven 1960). Although derived specifically for Atlantic herring, these criteria provided at least the framework for a standardized approach to the collection of maturity observations.

In February 1958, the BCF staff initiated a monthly sampling program for haddock (*Melanogrammus aeglefinus*) in which standardized tows were taken at a fixed station located at 42°15' N latitude by 70°00' W longitude (about 15 miles northeast of Provincetown, Massachusetts) in depths of 100-120 meters (Bureau of Commercial Fisheries 1958, 1959). In this project (the so-called "Highlands Ground Study"), biological information was collected, tagging operations were performed, and 100 haddock from each sampling period were retained for laboratory studies of liver condition (Bureau of Commercial Fisheries 1959), food habits (Wigley and Theroux 1965), and gonad developmental stages (Bureau of Commercial Fisheries 1959).

During the earlier stages of the NEFC's bottom trawl survey program (1963-70), only haddock and yellowtail flounder (*Limanda ferruginea*) were sampled for age structures and maturity stage data. The maturity classification scheme employed during this period was essentially the eight-stage scheme recommended by FAO (Kesteven 1960), except that specific refinements for haddock were introduced based on results from the Highlands Ground Study (R. Livingstone, Jr. personal communication[1]). Maturity observations were limited to those fish sampled for age and growth, and maturity stage data were recorded directly onto the coin envelopes used to retain age samples. It is important to note that the pool of seagoing personnel participating on these early research survey cruises was small in number, but highly experienced; interpretations of maturity stages for the two species over this period were probably very consistent.

EVOLUTION OF MATURITY SAMPLING

1970-76

By 1970, the need for age-based analytical assessments resulted in the expansion, over several years, of at-sea survey sampling of age structures and maturity stages to several other species: Atlantic cod (*Gadus morhua*), pollock (*Pollachius virens*), and red hake (*Urophycis chuss*) in 1970; Atlantic mackerel (*Scomber scombrus*), silver hake (*Merluccius bilinearis*), Atlantic herring, and alewife (*Alosa pseudoharengus*) in 1973; Acadian redfish (*Sebastes fasciatus*), windowpane (*Scophthalmus aquosus*), and summer flounder (*Paralichthys dentatus*) in 1975; and American plaice (*Hippoglossoides platessoides*) and winter flounder (*Pseudopleuronectes americanus*) in 1976. The diffi-

[1] R. Livingstone, Jr., c/o National Marine Fisheries Serv., Water St., Woods Hole, MA 02543.

Table 1. Seven-stage Hjort gonad maturity scale [from Hjort (1910)] developed for Atlantic herring and used during early phases of NEFC bottom trawl survey program

Stage	Description and Criteria
I	Virgin individuals: very small sexual organs close under vertebral column; ovaries wine-colored, torpedo-shaped, about 2-3 cm long and 2-3 mm thick; eggs invisible to naked eye; testes whitish or grayish brown, knife-shaped, 2-3 cm long and 2-3 mm broad
II	Maturing virgins or recovering spents: ovaries somewhat longer than half the length of ventral cavity, about 1 cm diameter; eggs small, but visible to naked eye; milt whitish; [testes] somewhat bloodshot, of same size as ovaries, but still thin and knife-shaped
III	Sexual organs more swollen, occupying about half of ventral cavity
IV	Ovaries and testes occupying almost two thirds of ventral cavity; eggs not transparent; milt whitish; swollen
V	Sexual organs filling ventral cavity; ovaries with some large transparent eggs; milt white, not yet running
VI	Roe and milt running (spawning)
VII	Spents: ovaries slack with residual eggs; testes baggy, bloodshot

Table 2. Eight-stage FAO maturity classification scheme [from Buckmann (1929) in Kesteven (1960)]

Stage	Description and Criteria
I	Virgin: very small sexual organs close under vertebral column; testis and ovary transparent, colorless to gray; eggs invisible to naked eye
II	Maturing virgin and recovering spent: testis and ovary translucent, gray-red; length half, or slightly more than half, length of ventral cavity; single eggs can be seen with magnifying glass
III	Developing: test[e]s and ovaries opaque, reddish with blood capillaries; occupy about half of ventral cavity; eggs visible to eye as whitish granular
IV	Developed: testis reddish white; no milt drops appear under pressure; ovary orange-reddish; eggs clearly discernible, opaque; testis and ovary occupy about two thirds of ventral cavity
V	Gravid: sexual organs filling ventral cavity; testis white, drops of milt fall with pressure; eggs completely round, some already translucent and ripe
VI	Spawning: roe and milt run with slight pressure; most eggs translucent with few opaque eggs left in ovary
VII	Spent: not yet fully empty; no opaque eggs left in ovary
VIII	Resting: testis and ovary empty, red; a few eggs in state of reabsorption

culty of the activity was compounded by the addition of a regular spring survey in 1968 and intermittent summer and winter surveys. The need for generalized maturity classification criteria which would be applicable over a range of species and seasons was very apparent.

Other important changes occurred as well. In 1973, the International Commission for the Northwest Atlantic Fisheries established catch quotas for several species, which necessitated greater stock assessment involvement by the United States as well as the addition of several new staff members to the Woods Hole Laboratory. These changes, coupled with the natural attrition of experienced seagoing biologists, led to a decline in survey experience levels and further increased the need to: (1) compile and summarize

maturity staging criteria, (2) provide training in maturity determinations, and (3) develop a field guide for shipboard use.

A limited effort at broadening criteria was made in the early 1970s by the Age and Growth Unit at the Woods Hole Laboratory, which generated species-specific staging criteria for yellowtail flounder, Atlantic herring, Atlantic mackerel, and silver hake (Tables 3A - 3D; J. Penttila, personal communication[2]). In 1972, the Age and Growth Unit introduced age sample envelopes listing the eight maturity stages; the recorder would simply circle the appropriate stage during the at-sea processing phase of individual fish observations. Beginning in 1973 and continuing to the present, all Atlantic herring, river herring (alewife and blueback herring, *Alosa aestivalis*), and Atlantic mackerel collected for age sampling were frozen at sea and processed (including maturity staging) at the Woods Hole Laboratory by Age and Growth Unit personnel.

A more comprehensive attempt to develop a more generalized set of criteria was undertaken by R. Livingstone, Jr., head of the Spawning and Fecundity Studies Investigation at the Woods Hole Laboratory. From joint research conducted during 1969-70, Livingstone and R.G. Halliday of the Canadian Department of Fisheries and Oceans revised existing survey maturity criteria with particular reference to Atlantic cod and pollock (R. Livingstone, Jr., personal communication[3]). Their revisions were based upon observations made during survey cruises conducted by both countries and augmented by the systematic seasonal sampling of fish landed in the port of Boston, Massachusetts. Also, color photographs were prepared of the various maturity stages for several species, by sex, and compiled into a manual for at-sea reference. This manual included detailed descriptions of the maturity stages devised by Livingstone and Halliday (Table 4), as well as instructions for at-sea maturity sampling (see Appendix), and became part of the survey field reference collection in 1971. Although the maturity manual was expanded and improved over the next few years, the basic criteria remained unchanged until 1977.

1977-84

In 1977, responsibility for the collection of maturity data aboard survey cruises was transferred from the NEFC's Woods Hole Laboratory to its Sandy Hook (New Jersey) Laboratory. W. Morse, the principal investigator, simplified the existing eight-stage maturity classification scheme to five stages (Table 5); this was achieved by combining stages R_1 and R_2 of Livingstone and Halliday into a new "Developing" category and by combining stages R_3, S_1, and S_2 into a "Ripe" category. This change went into effect for the spring 1977 bottom trawl survey. During this period, survey maturity sampling was expanded to include a total of 32 species.

In addition, maturity data for individual fish were transcribed from the Age and Growth Unit's age sample envelopes onto maturity logs, along with length, sex, station, and, during 1980-84, pathology information; these data were then entered into a computerized maturity data base maintained at the Sandy Hook Laboratory. This data base contained maturity information by fish length only, since age data were not added to data records. Data audits for the years 1977-81 were performed to remove gross outliers and to adjust data for small fish identified as mature which were discontinuous with the lower end of the mature spectrum to the immature category (W. Morse, personal communication[4]). Maturity ogives for numerous species were generated from these data using probit analysis (Morse 1979).

In 1982, maturity data collection responsibility reverted to L. O'Brien of the Resource Surveys Investigation at the Woods Hole Laboratory. Maturity data for the years 1982-84 were entered and archived by the Sandy Hook Laboratory, but not audited as described above. Pre-cruise meetings were initiated in 1982 for survey participants during which maturity sampling and staging criteria were reviewed with the use of color slides. Also in 1982, a spawning season chart (based on literature values) summarizing the approximate spawning seasons and sizes at first maturity for a variety of species was prepared for at-sea use (Table 6).

In 1983, a sixth maturity stage, "Ripe and Running," was added, and in 1984, an "Eyed" stage for viviparous female redfish was introduced; criteria for these stages are provided in Table 7. Also in 1984, an instructional video was developed highlighting maturity sampling techniques which is shown at the beginning of each survey cruise.

In 1984, the spawning season chart was revised twice. The first revision, used on the 1984 spring bottom trawl survey, partitioned existing maturity information into separate charts for Georges Bank and the Gulf of Maine (Tables 8 and 9) in relation to estimated spawning season peaks. The second revision, introduced on the 1984 fall survey, was based upon analyses of egg and larval data [first presented in Smith (1983) and later destroyed in a fire, but subsequently given in Smith (1985)] collected during the NEFC's Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP) (Table 10). This chart remains in use today.

1985-present

Beginning in 1985, age and maturity data for all fish were included in master data records prepared by the Fishery Biology Investigation (successor to the Age and

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Table 3A. Maturity stages derived by Woods Hole Laboratory Age and Growth Unit in early 1970s for yellowtail flounder, *Limanda ferruginea* (R = ripening, S = spawning)

Stage	Description and Criteria
Immature	**Males**: testes very small and undeveloped; pinkish color **Females**: ovary small; light pink jelly
Resting	**Males**: testes small and fairly hard; pinkish white; no milt **Females**: pink-red jelly (may be slightly granular); ovary larger
R_1	**Males**: some milt beginning to form; testes larger, not as hard; white color, or pink and white **Females**: ovary orange-peach color, granular appearance; ovary not full
R_2	**Males**: good deal of milt present, will flow if pressure applied; testes larger, white, soft (pink edge and white) **Females**: ovary peach color; eggs can be seen; ovary large, but not swollen
R_3	**Males**: milt flows readily when force applied; testes white and full **Females**: ovary peach color; eggs clearing; ovary very large, full, and swollen
S_1	**Males**: milt flows with gentle pressure; testes white, large, and very full **Females**: ovary peach color; mostly clear eggs; eggs flow with pressure; ovary full
S_2	**Males**: testes emptying somewhat, still white **Females**: ovary peach color; mostly clear eggs; ovary emptying
Recovering	**Males**: raw, red look to testes; milt present; testes large, empty **Females**: ovary peach color; eggs in jelly; ovary large and deflated

Table 3B. Maturity stages derived by Woods Hole Laboratory Age and Growth Unit in early 1970s for Atlantic herring, *Clupea harengus*

Stage	Description and Criteria
I	**Immature**: testes and ovaries very small, threadlike, 2-3 mm broad; testes grayish white or brownish red; ovaries pinkish or wine red; fish length < 21 cm
II	**Immature fish that will spawn next year:** testes and ovaries small, 3-8 mm broad; testes reddish or grayish brown-red; ovaries bright reddish color; eggs visible only with microscope
III	**Ripening, early stage:** testes and ovaries occupy about half of ventral cavity, 1-2 cm broad; testes grayish or brownish red; ovaries orange-red; eggs small, but visible and granular
IV	**Ripening, mid stage:** testes and ovaries almost as long as body cavity; testes reddish yellow with blood ves-sels clearly visible; ovaries orange-red or pale yellow-red; eggs larger, opaque with only a few clear
V	**Ripe:** testes and ovaries fill body cavity; milt and eggs do not flow, but can be extruded by pressure; testes yellowish white or milk white with no reddish color and blood vessels not visible; ovaries yellowish; eggs large and mostly clear
VI	**Spawning:** testes and ovaries ripe and emptying; milt and eggs flow freely; testes white or pale yellowish white with no blood vessels visible; ovaries yellowish; eggs large and clear
VII	**Spent:** testes and ovaries baggy, flabby, and bloodshot; testes empty or with residual milt; ovaries empty or with few residual eggs
VIII	**Resting:** testes and ovaries firm and larger than in Stage II; walls striated with blood vessels prominent; testes brownish red; ovaries wine red; eggs not visible to naked eye (Stage VIII to Stage III)

NOTE: Forward tips of testes blunter than ovaries; testes brownish or grayish red, while ovaries pinkish or wine red; testes smooth in appearance, while ovaries more wrinkled.

Table 3C. Maturity stages derived by Woods Hole Laboratory Age and Growth Unit in early 1970s for Atlantic mackerel, *Scomber scombrus* (R = ripening, S = spawning, R_e = recovering)

Stage	Description and Criteria
Immature	**Males**: knife-edge to testes; pink, clear, small **Females**: rounded edge to ovaries; pink, clear, small
Resting	**Males**: pink, opaque, larger **Females**: pink, opaque, larger
R_1	**Males**: pink-yellow; some milt **Females**: pink-yellow; granular appearance
R_2	**Males**: yellow-pink; more milt **Females**: yellow-pink; eggs can be seen quite easily
R_3	**Males**: yellowish; much milt; will flow with pressure **Females**: yellowish; eggs clearing
S_1	**Males**: yellow-white; testes full; milt flows with little pressure **Females**: yellowish; ovaries full; most eggs clear
S_2	**Males**: yellow-white; testes emptying; milt flows with little pressure **Females**: yellowish; ovaries emptying; all eggs clear
R_e	**Males**: yellowish, bloody appearance; some milt; testes large, but empty **Females**: yellowish, bloody appearance; eggs decomposing; ovaries large, but empty

Table 3D. Maturity stages derived by Woods Hole Laboratory Age and Growth Unit in early 1970s for silver hake, *Merluccius bilinearis* (R = ripening, S = spawning, R_e = recovering)

Stage	Description and Criteria
Immature	**Males**: testes white, small, like a twisted string **Females**: ovaries small, light pinkish white color, clear; little development of blood vessels
Resting	**Males**: testes white, larger, twisted with lobes **Females**: ovaries larger, pink jelly, and opaque; some blood vessels
R_1	**Males**: testes larger than in Resting stage; some milt present; network collecting milt is pink and not large **Females**: ovaries peach color, granular; large, but not full; blood vessels developing
R_2	**Males**: more milt present; network larger **Females**: ovaries peach color; eggs visible; more blood vessels; ovaries large and full
R_3	**Males**: testes full; network full of milt **Females**: ovaries peach color; eggs clearing; blood vessels prominent; ovaries large and full
S_1	**Males**: milt flows with pressure; network and testes full **Females**: mostly clear eggs; eggs flow with pressure; ovaries large and swollen
S_2	**Males**: testes emptying; network still full of milt **Females**: ovaries emptying; clear eggs; no jelly
R_e	**Males**: testes raw, red, large with some milt; deflated **Females**: ovaries peach color; eggs in jelly; ovaries large, but deflated; still many blood vessels present

Table 4. Maturity staging criteria developed by Livingstone and Halliday (unpublished) and used during NEFC bottom trawl surveys, 1970-76

Stage	Designation	Description and Criteria
		Females
Immature	I	**General**: small membrane, thin, translucent; pink to wine colored; eggs not visible to naked eye **Variations**: smaller fish that have actually spawned, generally late in season, and in Recovering (R_c) or Resting (R_t) condition, but resemble stage I; ovary larger than stage I; membrane opaque and purplish to grayish blue, to reddish in late Resting stage; R_c stage contains remains of unspawned eggs; R_t stage usually slightly swollen and jelly-like in center (split open to examine interior)
Ripening 1	R_1	**General**: noticeable increase in growth as ovary becomes kidney-shaped organ; membrane with blood vessel network, and ovary light yellow to orange in color as yolked eggs, barely visible to eye, begin development prior to spawning **Variations**: during fall and early winter, some large haddock in this condition, but ovary more pink to red
Ripening 2	R_2	**General**: continued increase in growth, and ovary may occupy 1/3 to 1/2 of body cavity; membrane with developed blood vessel network, and color yellow-orange to pink-salmon; yolked eggs, now easily visible, give membrane distinct granular appearance (this is stage to collect for fecundity studies) **Variations**: ovary in Atlantic cod somewhat lighter in color than in haddock (no observations for pollock)
Ripening 3	R_3	**General**: continued increase in growth, and ovary may nearly fill body cavity, accounting for 15-20 % of total body weight; membrane appears speckled- blotched as unequal portions of yolked eggs enlarge and become transparent; color highly variable from salmon or light orange to brick red; center of ovary may contain liquid and transparent eggs (spawning has not yet started, but cut open to make certain) **Variations**: some fish may appear to be stage R_2 by outward appearance, but on being split open will reveal tapioca- like mass of ripe-transparent and opaque-yolked eggs
Spawning 1	S_1	**General**: liquid state; ovary may fill body cavity; membrane appears thin and blotched due to presence of unequal portions of yolked-opaque and transparent eggs; color variable, reddening as spawning proceeds; fluid eggs run from vent under slightest pressure **Variations**: as with stage R_3, outward appearance may be deceiving because of large numbers of liquid eggs in center; it is essential to split open these questionable examples, especially when catches contain individuals in spawning condition
Spawning 2	S_2	**General**: ovary as above, but would appear less than half its former size, and somewhat flaccid; membrane thin and appearing more purplish; contents mostly liquid ripe eggs (haddock ovary weighed 134 g, perhaps reduced in weight by factor of 6 from S_1 size) **Variations**: no observations
Spent-Recovering	R_c	**General**: greatly reduced in size; purplish and baggy; may contain varying amounts of unspawned eggs that will be absorbed before next year's spawning **Variations**: small individuals that spawn late in season may have ovary resembling Immature stage (see variations for Immature stage); questionable stages should be cut open and scraped with knife for evidence that spawning has taken place (a few unspawned eggs should be present)
Resting	R_t	**General**: recycling for next year's spawning has begun; color whitish to grayish blue, but later reddening; membrane toughens and ovary appears slightly swollen; interior jelly-like in consistency (eggs not visible), except for occasional globs of degenerating eggs still being absorbed **Variations**: no observations

Table 4--*Continued*

Stage	Designation	Description and Criteria
		Males
Immature	Im	**General**: small, narrow crimped ribbon; colorless to gray; membrane slightly translucent; blood capillaries not visible to eye **Variations**: small males may develop precoci[ous]ly and produce milt from very small testes
Ripening 1	R_1	**General**: growth noticeable, becomes slightly wavy and pink as blood vessel network becomes more visible
Ripening 2	R_2	**General**: lobes of testes increase in size and may acquire reddish tinge from continued development of blood vessels; testes may now occupy up to 1/2 of body cavity
Ripening 3	R_3	**General**: testes may fill body cavity or be less enlarged (more variable in males than females); lobes become very swollen, losing some redness and often turning white to chalk white; membrane weak and yield[s] milt easily under pressure (*e.g.*, squeezing lobe with thumb and forefinger), but questionable whether spawning has begun
Spawning 1,2	S_1,S_2	**General**: testes extremely fragile and liquid; freshly caught specimens may spew milt from vent just in process of handling; testes variable in size; membrane chalk white as S_1 or later dis-coloring and reddening around edges as spawning proceeds as S_2
Spent-Recovering	R_c	**General**: testes greatly shrunken, ragged in appearance; lobes rimmed with brown-red discoloration; small pockets of milt may still remain
Resting	R_t	**General**: continued shrinking in size; lobes small and thin; color yellowish to off-white

Table 5. Five-stage maturity classification scheme introduced by Morse (unpublished) in 1977 [see Morse (1979)]

Stage	Designation	Description and Criteria
Immature	I	**Females**: small, translucent membrane usually colorless or pink. Gadids: very thin, ribbon-like tissue lying along dorsal wall of gut cavity. Flatfish: small translucent organ located at posterior curve of gut cavity **Males**: testes colorless to gray, often more opaque than ovaries and appear more flattened
Developing	D	**Females**: ovaries opaque and enlarged with blood vessels becoming prominent; small, opaque eggs present as ovary develops to occupy 2/3 of ventral cavity. Flatfish: ovary extending posteriorly from gut cavity; bright yellow and firm texture **Males**: testes opaque with lobed or wavy appearance; color variable from red or pink to gray or white; milt may or may not be present in small amounts; will occupy up to 1/2 body cavity. Flatfish: appears as oval gray to whitish tissue at posterior curve of gut cavity
Ripe	R	**Females**: this stage is to be used when female is ready to spawn, is spawning, or has not yet completed spawning; ovary may fill body cavity; eggs abundant and visible through ovary wall; a few to many transparent eggs may be present; as part of eggs are spawned, ovary may have bloodshot appearance, but eggs still numerous, color variable from bright orange to red. Note: if eggs run from vent under slight pressure to abdomen, designate as RR (Ripe and Running) **Males**: testes large, 2/3 of gut cavity filled, color white or pinkish or edges turning brown; milt present when testes squeezed or cut open
Spent	S	**Females**: ovaries flaccid, usually reddish to purple, and sac-like; interior often quite fluid with a few translucent eggs present; ovarian wall opaque **Males**: testes reduced in size, very little or no milt present when cut; color gray to brown
Resting	Rt,T	**Females**: ovaries much reduced in size, color purple to pink; interior jelly-like with no eggs visible; no prominent blood vessels **Males**: testes small, opaque, and shrunken in appearance; color may be brownish to gray

Table 6. Approximate spawning seasons and lengths (cm) at first maturity of 24 finfish species derived from literature search and used during 1982-83 surveys

Species	Spawning Season	Males		Females	
		Mean	Range	Mean	Range
Acadian redfish	May-Aug	22	17-32	24	18-29
Alewife	Apr-May	28	24-32	31	25-34
American plaice	Mar-May	27	21-38	34	25-45
Atlantic cod	Dec-Apr	54	41-65	50	38-65
Atlantic herring	Aug-Oct	27	23-37	26	23-37
Atlantic mackerel	May-Jun	31	29-35	31	29-34
Bluefish	Jun-Aug	40	-	40	-
Butterfish	Jun-Aug	12	11-17	13	11-17
Fourspot flounder	Apr-Nov	26	23-30	28	25-31
Goosefish	Jun-Sep	41	31-48	41	37-52
Haddock	Feb-May	42	32-53	43	32-55
Longhorn sculpin	Nov-Feb	21	18-26	21	18-26
Ocean pout	Sep-Oct	40	31-46	35	28-45
Pollock	Nov-Feb	52	43-65	49	37-66
Red hake	May-Aug	25	22-33	28	21-39
Scup	May-Jul	15	13-21	15	13-22
Silver hake	May-Oct	25	20-35	27	20-40
Summer flounder	Oct-Apr	25	23-31	28	25-32
Weakfish	May-Jul	28	20-42	30	21-39
White hake	Oct-Apr	43	36-53	48	35-59
Windowpane	May-Aug	19	15-30	22	18-29
Winter flounder	Jan-May	25	20-34	26	19-38
Witch flounder	Mar-Aug	33	26-39	35	28-46
Yellowtail flounder	Mar-Aug	24	21-37	28	22-36

Table 7. Description and criteria for maturity stages "Ripe and Running" and "Eyed" added to five-stage classification scheme in 1983-84

Stage	Designation	Description and Criteria
Ripe and Running	RR,A,U	**Males**: same criteria as Ripe, but milt flows freely from vent with little or no pressure on abdomen **Females**: this stage denotes a ripe female with eggs flowing from vent with little or no pressure on abdomen
Eyed	E	**Female redfish only**: ovary large and robust, with transparent membrane, with dark spotted eggs which are developing larvae

Growth Unit). Special projects conducted subsequent to 1985 have resulted in a much longer time series of maturity data for some species. This represents the first time that length, age, sex, and maturity information appeared on the same data record, a feature which has greatly facilitated maturity analyses.

Starting in autumn 1986 and continuing to the present, maturity workshops have been held after each survey leg in which fresh fish captured during the survey are dissected and displayed for training and discussion. At the conclusion of the survey season, a voluntary "quiz" is administered to seagoing personnel to help identify problem species and maturity stages, and to evaluate the magnitude of error inherent within maturity staging data. Additionally, samples are taken for histological analysis in an attempt to clarify and improve macroscopic criteria.

A new initiative to upgrade the photographic field guide resulted in the introduction of a simplified, waterproof deck reference in spring 1989. In a special study for Atlantic cod during 1987-88, gonad and body weights of individual fish were measured at sea to generate gonadosomatic indices. The possibility that such indices might be used to audit maturity staging data is currently being investigated.

Based on the ongoing work mentioned above, macroscopic staging criteria have received a new revision (Table 11), resulting in the most complete and species-specific set of criteria to date. These criteria were first used on the autumn 1989 survey, and represent the culmination of years of evolution, refinement, and revision.

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REFERENCES CITED

Buckmann, A. 1929. Die methodik fischereibiologischer unter-suchungen an meeresfischen. *Abderhalden, handbuch der biologischen arbeitsmethoden* 9 (6,1). Urban und Schwarzenberg, Berlin. 194 pp.

Bureau of Commercial Fisheries. 1958. Annual report of the Woods Hole Laboratory for the year ending June 30, 1958. Available *from* National Marine Fisheries Service, Water St., Woods Hole, MA 02543. 78 pp.

Bureau of Commercial Fisheries. 1959. Annual report of the Biological Laboratory, Woods Hole, Mass., for the year ending June 30, 1959. Available *from* National Marine Fisheries Service, Water St., Woods Hole, MA 02543. 52 pp.

Hjort, J. 1910. Report on herring investigations until January 1910. *Cons. Perma. Int. Explor. Mer Publ. Circ.* No. 53. 174 pp.

Kesteven, G.L., ed. 1960. Manual of field methods in fisheries biology, provis. ed. *FAO Manuals Fish. Sci.* No. 1. 152 pp.

Livingstone, R., Jr., and R.G. Halliday. [Undated.] Unpublished table on maturity staging criteria. Available *from* National Marine Fisheries Service, Water St., Woods Hole, MA 02543.

Morse, W.W. 1979. An analysis of maturity observations of 12 groundfish species collected from Cape Hatteras, North Carolina to Nova Scotia in 1977. Nat. Mar. Fish. Serv., *Sandy Hook Lab. Rep.* No. SHL 79-32. 21 pp.

Smith, W.G. 1983. Spawning seasons for principal coastal species. Nat. Mar. Fish. Serv., *Sandy Hook Lab. Rep.* No. SHL 83-08. [Unavailable; all copies destroyed by fire.]

Smith, W.G. 1985. Temporal and spatial spawning patterns of the principal species of fish and invertebrates in the Georges Bank region. Nat. Mar. Fish. Serv., *Sandy Hook Lab. Rep.* No. SHL 85-04. 35 pp.

Wigley, R.L., and R.B. Theroux. 1965. Seasonal food habits of Highlands Ground haddock. *Trans. Amer. Fish. Soc.* 94: 243- 251.

Table 8. Approximate spawning seasons and probable maturity stages in spring and autumn for 20 finfish species from Georges Bank based on analysis of survey maturity data

Species	Season (peak)	Approximate Maturity Stage[1]	
		Spring	Autumn
Acadian redfish	Apr-Aug (Jun-Jul)	D-R-E	D-R-S
American plaice	Feb-Jun (Apr-May)	D-R	T
Atlantic cod	Nov-May (Feb-Mar)	S-T	T-D-R
Atlantic herring	Sep-Dec (Sep-Oct)	T	D-R-S
Atlantic mackerel	Apr-Jul (May-Jun)	D-R	T
Butterfish	Jun-Sep (Jun)	T-D	S-T
Fourspot flounder	Jun-Aug (Jul-Aug)	T-D	S-T
Goosefish	Jun-Aug (Jun-Jul)	D	S-T
Haddock	Jan-May (Mar-Apr)	D-R-S-T	T-D
Longhorn sculpin	Nov-Feb (Dec-Jan)	S-T	T-D
Ocean pout	Sep-Oct (Sep)	T	R-S
Pollock	Oct-Mar (Dec-Jan)	S-T	T-D
Red hake	May-Sep (Jun-Jul)	T-D	S-T
Silver hake	Apr-Oct (May-Aug)	T-D	S-T
Summer flounder	Sep-Nov (Oct)	T	D-R-S
White hake	Oct-May	D-R-S-T	T-D-R
Windowpane	Jun-Oct (Jul-Aug)	T-D	R-S-T
Winter flounder	Mar-May (Apr)	D-R-S	T
Witch flounder	Apr-Aug (May-Jun)	D-R	T-D
Yellowtail flounder	Apr-Aug (May-Jun)	T-D	S-T

[1] D = Developing; R = Ripe; E = Eyed; S = Spent; and T = Resting.

Table 9. Approximate spawning seasons and probable maturity stages in spring and autumn for 18 finfish species from Gulf of Maine based on analysis of survey maturity data

Species	Season (peak)	Approximate Maturity Stage[1]	
		Spring	Autumn
Acadian redfish	Apr-Aug (Jun-Jul)	D-R-E	D-R-S
American plaice	Feb-Jun (Apr-May)	D-R	T
Atlantic cod	Nov-May (Mar-May)	R-S-T	T-D-R
Atlantic herring	Aug-Dec (Sep-Oct)	T	D-R-S
Atlantic mackerel	May-Jul (Jun)	D-R	T
Butterfish	Jun-Sep (Jul)	T-D	S-T
Goosefish	Jun-Sep (Jun-Jul)	D	S-T
Haddock	Feb-May (Mar-Apr)	D-R-S-T	T-D
Longhorn sculpin	Nov-Feb (Dec-Jan)	S-T	T-D
Ocean pout	Sep-Oct (Sep)	T	R-S
Pollock	Oct-Mar (Dec-Jan)	S-T	T-D
Red hake	May-Sep (Jun-Jul)	T-D	S-T
Silver hake	Jun-Oct (Jul-Aug)	T-D	S-T
White hake	Nov-Apr	R-S-T	T-D-R
Windowpane	Jun-Oct (Jul-Aug)	T-D	S-T
Winter flounder	Apr-May (Apr)	D-R-S	T
Witch flounder	Apr-Aug (May-Jun)	D-R	T
Yellowtail flounder	Apr-Aug (May-Jun)	T-D	T

D = Developing; R = Ripe; E = Eyed; S = Spent; and T = Resting.

Table 10. Approximate spawning seasons (peak in parentheses) by region of 42 species of finfish and shellfish derived from MARMAP egg and larval data [from Smith (1983)]

	Middle Atlantic	Southern New England	Georges Bank	Gulf of Maine
Boreal (shallow) species				
Atlantic herring	None reported	Oct-Dec (Oct)	Sep-Dec (Sep-Oct)	Aug-Dec (Sep-Oct)
American plaice	None reported	Feb-Jun (Apr-May)	Feb-Jun (Apr-May)	Feb-Jun (Apr-May)
Atlantic cod	Nov-Apr (Mar-Apr)	Nov-May (Nov-Mar)	Nov-May (Feb-Mar)	Nov-May (Mar-May)
Pollock	Oct-Mar (Dec-Jan)	Oct-Mar (Dec-Jan)	Oct-Mar (Dec-Jan)	Oct-Mar (Dec-Jan)
Haddock	None reported	Jan-May (Mar-Apr)	Jan-May (Mar-Apr)	Feb-May (Mar-Apr)
Boreal (deep) species				
Witch flounder	Apr-Aug (May-Jun)		Apr-Aug (May-Jun)	Apr-Aug (May-Jun)
Acadian redfish	None reported	Apr-Jul (May-Jun)	Apr-Aug (Jun-Jul)	Apr-Aug (Jun-Jul)
Cusk	None reported	Apr-Jul (Apr-May)	Apr-Jul (Apr-May)	Apr-Jul (Apr-May)
Atlantic wolffish	None reported	Nov-Jan (peak unknown)	Nov-Jan (peak unknown)	Nov-Jan (peak unknown)
Atlantic argentine	None reported	None reported	None reported	Mar-May (Mar)
Thorny skate	None reported	Probably none	All year (Apr-Sep)	All year (Apr-Sep)
Warm water species				
Bluefish	May-Aug (Jul)	May-Aug (Jul)	None reported	None reported
Northern searobin	Jun-Oct (Aug-Sep)		None reported	None reported
Scup	May-Aug (May-Jun)	May-Aug (May-Jun)	None reported	None reported
Longfin squid	Apr-Sep (Jun&Sep)	Apr-Sep (Jun)	Apr-Jul (Jun)	Jul (Jul)
Fourspot flounder	May-Sep (Jul)	Jun-Aug (Jul)	Jun-Aug (Jul-Aug)	None reported
Summer flounder	Sep-Dec (Oct-Nov)	Aug-Nov (Oct)	Sep-Nov (Oct)	None reported
Butterfish	May-Sep (Jun-Jul)	May-Sep (Jul)	Jun-Sep (Jul)	Jun-Sep (Jul)
Eurythermal species				
Ocean pout	None reported	Sep-Oct (Oct)	Sep-Oct (Oct)	Sep-Oct (Sep)
Longhorn sculpin	None reported	Nov-Feb (Dec-Jan)	Nov-Feb (Dec-Jan)	Nov-Feb (Dec-Jan)
Yellowtail flounder	Mar-Aug (May)	Apr-Aug (May-Jun)	Apr-Aug (May-Jun)	Apr-Aug (Jun)
Winter flounder	Mar-May (May)	Feb-May (Feb-Mar)	Mar-May (Apr)	Apr-May (Apr)
Windowpane	May-Nov (May&Sep)	May-Nov (Sep)	Jun-Oct (Jul-Aug)	Jun-Oct (Jul-Aug)
Little skate	All year (Nov-Jan&Jul)	All year (Nov-Jan&Jan-Jul)	All year (Nov-Jan&Jul)	All year (Oct-Jan)
Winter skate	None reported	All year (Apr-May&Nov-Feb)	All year (Apr-May&Nov)	Aug-Nov (Sep)
Stenothermal species				
Red hake	Mar-Oct (Jun-Jul)	Mar-Oct (Aug-Sep)	May-Sep (Jun-Jul)	May-Sep (Jun-Jul)
Spiny dogfish	Nov-Feb (Jan)	Nov-Feb (Jan)	Sep-May (Jan-Mar)	None reported
Silver hake	Apr-Oct (Sep)	Apr-Oct (Jun)	Apr-Oct (May-Aug)	Jun-Oct (Jul-Aug)
Sea raven	None reported	Oct-Dec (Nov-Dec)	Oct-Dec (Nov)	Oct-Dec (Nov)
Cunner	Apr-Oct (Jun)	Apr-Oct (Jun)	May-Aug (May-Jun)	Jun-Sep (Jun)
American lobster	May-Aug (May-Jun)	May-Aug (May-Jul)	Jun-Aug (Jul-Aug)	Jul-Aug (Jul-Aug)
White hake	Oct-Apr (Dec-Feb)	Oct-Mar (Dec-Feb)	Oct-May (peak unknown)	Nov-Apr (peak unknown)
Goosefish	Mar-Aug (May-Jun)	Apr-Aug (Jun)	Jun-Aug (Jun-Jul)	Jun-Sep (Jun-Jul)
Other species				
Alewife	Mar-Apr (Apr)	Mar-Apr (Apr)	None reported	Apr-May (May)
Blueback herring	Apr-Jun (May)	Apr-Jun (May)	None reported	May-Jun (Jun)
Northern sand lance	Nov-Mar (Jan-Feb)	Nov-Mar (Jan-Feb)	Nov-Mar (Jan-Feb)	Dec-Apr (Feb-Mar)
Atlantic mackerel	Apr-Jun (Apr-May)	Apr-Jun (May)	Apr-Jul (May-Jun)	May-Jul (Jun)
Gulf Stream flounder	May-Oct (Jul-Aug)	Jun-Oct (Jul-Aug)	Jun-Oct (Jul-Aug)	None reported
Atlantic rock crab			All year (Apr-Jun)	All year (Apr-Jun)
Jonah crab		Jul (Jul)		
Sea scallop	Jul-Sep (Aug)	Jul-Sep (Aug)	Sep-Oct (Sep-Oct)	Aug-Oct (Aug-Sep)
Swordfish	None reported	None reported	None reported	None reported

Table 11. Current maturity staging criteria used during NEFC bottom trawl surveys

Stage	Code	Description and Criteria
		Females
Immature	I	Ovary paired, tube-like organ, small relative to body cavity; thin, transparent outer membrane; contains colorless to pink jell-like tissue with no visible eggs
		Butterfish: ovary paired and flattened, with striations or wrinkles in ovary wall
Developing	D	Ovaries enlarge to occupy up to 2/3 of body cavity; if blood vessels present, they become prominent; ovary has granular appearance as yellow to orange yolked eggs develop
Ripe	R	Enlarged ovaries may fill entire body cavity; mixture of yellow to orange yolked eggs and hydrated or "clear" eggs present (50% or more clear eggs denotes ripe ovary, while less than 50% denotes developing ovary)
Eyed	E	Acadian redfish only: ovary large and robust with transparent membrane and with dark spotted eggs which are developing larvae
Ripe and Running	U	Ripe female with eggs flowing from vent with little or no pressure to abdomen
Spent	S	Ovaries flaccid, sac-like, similar in size to ripe ovary; color red to purple; ovary wall thickening, becoming cloudy and translucent vs. transparent as in ripe ovary; some eggs, either clear or yolked, may still be present, however most adhere to ovary wall; therefore, CUT OPEN OVARY to make sure there is no mass of eggs in center of ovary (as in stages D and R)
Resting	T	Gonad reduced in size relative to ripe ovary, but larger than as immature; interior jell-like with no visible eggs
		Flounders: ovary does not appear to reduce in size relative to body cavity as much as in gadids, and interior usually yellow or orange; apparently, eggs spawned and after a short spent stage, ovary develops up again with yolked eggs which are small and do not get any larger until prior to next spawning season; ovary wall thicker and tougher than ripe ovary wall, and wall is cloudy or translucent, rather than clear as in ripe ovary
		Gadids: ovary wall thick and tough with purplish membrane and no prominent blood vessels; since there is not a fresh blood supply, vessels more purple than bright red
		Silver hake: exception to above, this species more similar to flounders; eggs never seem to resorb into a jell-mass, but ovary continues to reduce in size while maintaining yellow-orange color of yolked eggs
		Males
Immature	I	Testes small relative to body cavity, colorless to gray, and translucent
		Butterfish: similar in appearance to ovary, with smooth wall vs. striations in female
		Flounders: testis triangular, located at posterior edge of gut cavity; other testis in same position on opposite side
		Winter flounder: anterior portion similar to other flounders, however posterior portion extends back similar to ovary of females; shape of extreme posterior portion of testis different from female: instead of coming to a point as in female, endpoint is rounded, and testis more flattened than round as it extends posteriorly
		Gadids: testes narrow and elongate with many lobes giving appearance of crimped ribbon

Table 11.--*Continued*

Stage	Code	Description and Criteria
		Males
		Atlantic herring, Atlantic mackerel, scup: similar in appearance to ovary, but there is an edge to testis vs. being rounded in female
Developing	D	Testes enlarge and color is gray to off-white; texture of testis is a firm consistency with very little or no milt present
Ripe	R	Testes now very large, color chalk white, and consistency mostly liquid; milt will flow easily if testis cut
		Gadids: testes will appear to fill entire body cavity
Ripe and Running	U	Before cutting open fish, milt flows easily from vent with little or no pressure on abdomen; once cut open, milt flows easily and color is chalk white
Spent	S	Testes flaccid, not as full of milt and robust as in Ripe stage; may contain residual milt; edges or parts of testes starting to turn gray and milt recedes
		Gadids: edges of lobes reddish to brown, or gray, as milt recedes from edge
Resting	T	Testes shrunken in size relative to Ripe stage; color yellow, brown, or gray with little or no milt

APPENDIX: INSTRUCTIONS FOR AT-SEA MATURITY SAMPLING

CONTAINED IN PHOTO MANUAL PREPARED BY LIVINGSTONE

DETERMINING MATURITY STAGE

Color, size of the gonad in relation to the body cavity, and fish length are the most helpful criteria for identifying maturity stages.

DISTINGUISHING THE IMMATURE FROM THE RESTING STAGE

After spawning, the gonad shrinks in size so that in all but the older fish one is apt to call the "resting" gonad "immature." For haddock, Atlantic cod, and pollock, I have noted the following differences between the two stages:

1. The resting gonad is slightly larger than the immature gonad, a point obvious in older specimens.

2. The membrane of the resting ovary is usually opaque; it is translucent in the immature. It is also generally more leathery to the touch and in males looks dried up.

3. If cut open, the resting ovary often contains remains of unspawned eggs or resorbing eggs (evidence of spawning); the immature ovary is jell-like on the inside with no visible eggs except under magnification.

The resting phase lasts until the gonad is recycled for the next spawning season. Thus, in the autumn, we would expect most of the spring spawners to be in this condition.

RECORDING MATURITY DATA

Most maturity data are taken at the same time the age and growth samples are being processed. Sex and maturity stage are recorded on the scale envelopes. Some of the newer envelopes have maturity stage abbreviations printed on them, so the recorder simply circles the correct maturity stage. If the person staging the gonads is unsure, then the recorder should note the stage with a question mark or some such notation on the envelope. Maturity stages are copied onto maturity stage logsheets (provided for each cruise) during times of bad weather and at the discretion of the chief scientist.

When the species being processed in an age-and-growth sample is required for fecundity, then the recorder should note this information on the envelope as FEC-1 which would indicate that this was the first sample preserved for fecundity. Age data should always be taken with fecundity samples.

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